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Cartografie van de interactiegebieden in en rond Brussel: pendelverkeer, verhuizingen en telefoongesprekken

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AUTHOR'S NOTE

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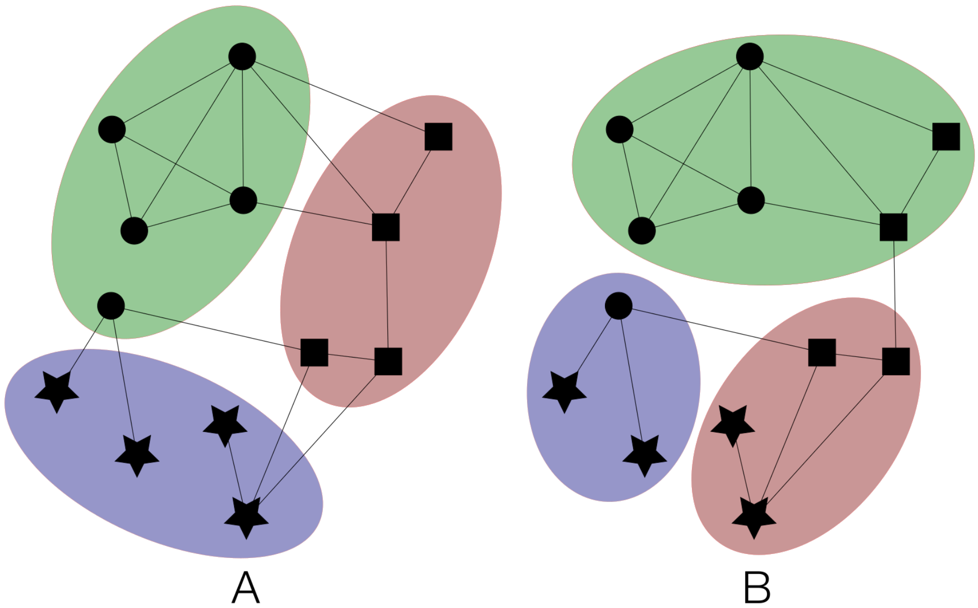
Introduction

1 From an administrative and political standpoint, Brussels is often referred to as the Brussels-Capital Region (BCR), yet the city spreads out over a much larger area whose boundaries are not officially and scientifically fixed [see for example Van Hecke, *et al.* 2007; Dujardin *et al.*, 2007; Thomas *et al.*, 2012; Boussauw *et al.*, 2012; Vandermotten, 2016]. Many different criteria and methods are used to define the Brussels metropolitan area, based on one or several socioeconomic and/or morphological variables, and on methods which are essentially related to the value thresholds of the variables used [see Dujardin *et al.*, 2007 or Thomas *et al.*, 2012]. In order to understand the space in and

around BCR, we propose the use of interactions w_{ij} between geolocations *i* and *j* within the networks, instead of using variables X_i characterising the places *i* (Figure 1).

Figure 1. Simplified representation of the detection of groups in a network based on (A) their similarities and (B) interactions



2 Economists and geographers agree that cities are characterised by high density in terms of population, buildings and urban functions with respect to their environment. Consequently, the agents (firms and households) are close and interact [see Anas *et al.*, 1998; Fujita and Thisse, 2013, p. 187 and following pages]. Cities have a concentration of a wide variety of agents, and these agents interact within economic and social networks. Proximity plays an important role in the formation of socioeconomic and human ties between agents [see for example Ioannides, 2012] and thus leads to "interaction fields" [Fujita and Thisse, 2013]. Delimiting urban areas and defining their composition is not a new topic in urban analysis, but there is no consensus regarding the methods used and the results obtained [Duranton, 2015; Dujardin *et al.*, 2007]. With the advent of big data and data science, new methods have been developed in terms of "community detection", with a community defined as a group of individuals (people, firms, etc.) in close interaction with each other. While these individuals are geolocated, the spatial projection of the community is related to the abovementioned "interaction fields". Despite their limits, these new methods and data have turned out to be effective tools for analysis, visualisation and urban planning [see for example Sagl *et al.*, 2014; Hao *et al.*, 2015].

3 Using data from the last census (changes of residence, commutes to and from the workplace) and telephone relations, this article aims to show which places are closely linked in and around Brussels and to map the "interaction basins" using a community detection method (the Louvain Method – see section 2). The article suggests areas based on relational data (w_{ij}), and provides a complement to the traditional territorial dynamics often based on the similarities between the characteristics X_i of places [Van Hamme *et al.*, 2016]. What are the strengths and weaknesses of these new approaches for urban analysis? Are the areas made up of places which are adjacent to one another?

Are the interactions between people or places in and around Brussels influenced by political (regional, linguistic) or physical boundaries (such as the canal or the Sonian Forest), and/or by other types of barrier [Dobruszkes and Vandermotten, 2006]? Does the shape of these areas depend greatly on the data used?

1. Data

1.1. Databases

4 Very typically, we have first used home-workplace travel (commuting) and residential migrations (moves) recorded during the last census (2011 - Census11), with all of the advantages and disadvantages of a census [Thomas *et al.*, 2009]. These "origin-destination (OD) matrices" have been available every ten years since 1981, and have the advantage of corresponding to definitions which are clear and stable over time, even though, since 2011, their construction is no longer based on the census survey but rather on existing administrative files. We therefore expect to define groups of places forming employment basins (commutes to and from the workplace) and migratory basins (moves), with levels of uncertainty related to the definitions of the workplace (head office used instead of the actual workplace, multiple or non-fixed workplaces, certain categories of workers not taken into account such as international civil servants, etc.) [see for example Verhetsel *et al.*, 2009] or of the place of residence (declared and not actual, multiple moves in a year, etc.) [see Eggerickx *et al.*, 2012].

5 Today, Information and Communication Technologies (ICT) allow more and more information to be collected in real time, thus offering a useful complement to the census [Debusschere *et al.*, 2017]. There is a huge amount of data, but unlike other parts of the world [see for example Liu *et al.*, 2015], the Belgian public and private authorities are cautious about making the data accessible, which is all the more true when the information is geocoded. Here, we use the telephone data from a major provider for April/May 2015. This included all of the mobile telephony calls between two numbers from the provider, which were geocoded by antennas at the time of the call; only the calls with at least one antenna in the former Province of Brabant were used, i.e. more than 13 million calls for the data collection period. As a reminder, the article by Blondel *et al.* (2010) concerned all of Belgium, with calls localised according to the billing address and geocoded at municipal level. Here, we have information at the *antenna* level at the moment of the call and therefore in the places where the caller and the callee were located. In this case as well, the data have limitations [Debusschere *et al.*, 2017] and only one telephone provider and one month of observation were taken into consideration; the nature (professional or private), length and object of the call were unknown, and the calls with the rest of Belgium/the world were not considered in the analysis. Despite these limitations, 13,4 million communications were considered in the analysis. The objective was to define telephone areas and therefore measure a type (among others) of social relationship during the day and during the night in and around Brussels.

1.2. Geographical choices

6 It is often difficult to define the boundaries of an area under study and its partitioning, particularly as they relate to a city for which there is no consensus as to its exact boundaries and which spreads out over three Regions (Brussels-Capital, Flemish Region and Walloon Region). In order to avoid any disputes, the former Province of Brabant constitutes the area under study here. This entity was created in 1815 and today is divided into three entities: the Brussels-Capital Region (1,2 million inhabitants), the Province of Flemish Brabant in the north (1,1 million inhabitants) and that of Walloon Brabant in the south (0,4 million inhabitants). The Province of Brabant includes most of the Brussels urban area [see Thomas *et al.*, 2012 for a summary] as well as Leuven, whose position in the metropolitan area is debated (Annexe 1).

7 While the maps proposed here constitute a close-up look at Brabant, the analyses were carried out for all of Belgium for migrations and commuting, which allows side effects to be avoided in a country with a dense urban network, without modifying the general appearance of the partitioning (tests conducted in Brabant with no relationship to the rest of the country, but not illustrated here – see also Thomas *et al.*, 2017). As mentioned in point 1.1., the same is not true for telephone calls where only the calls with at least one antenna in Brabant were used.

8 The proposed illustrations were made mainly at the scale of the 111 municipalities in the former Province of Brabant in order to be able to compare the results. This choice is justified by the fact that a municipality is the most specific geolocation obtained for moves and is therefore the smallest common denominator of the three analyses. The smallest spatial units for commuting are the statistical sectors (numbering 3 395), and for the telephones, Thiessen polygons[1] were drawn around the 1 168 antennas from the point (antenna) to the theoretical surface covered by these antennas. These polygons are, however, just a theoretical approximation of reality as (1) they do not consider the reality of the field (buildings which reduce the range and strength of the antennas, etc.) and (2) they never overlap, yet in reality, two neighbouring antennas may cover a common area (intersection of two spheres) [Zandbergen, 2009].

2. Method

9 From the world of the mathematical analysis of social networks, community detection methods have become popular in the past ten years in the analysis of complex networks [see for example Ratti *et al.,* 2010; Fortunato, 2010]. They are aimed at finding partitions (structures composed of communities) which maximise the density of intra-group connections with respect to the density of inter-group connections, and thus at finding dense sub-graphs in large graphs. Determined in an exact or heuristic manner, they are very efficient and offer a wide variety of methods allowing weighted and directed connections, hierarchical structures, and even the overlapping of areas depicted in this way. A popular method for detecting communities consists in calculating a number for each partition (referred to as modularity of the partition) which quantifies the quality of the partitioning, and then in finding the maximal modularity partition [Newman and Girvan, 2004]. The quick calculation of a partition with very good – but not necessarily maximal – modularity is possible using the Louvain Method [Blondel *et al.*, 2008]. This is a heuristic method which maximises

modularity in two successive and iterative stages. In the first stage, the method groups into communities the nodes with privileged exchanges which maximise modularity. Once all of the nodes are classified, the Louvain Method moves on to the second stage, whereby the nodes in each community merge into supra-nodes; these therefore represent the communities formed in the first stage. Then, the Louvain Method begins the first stage again and seeks to group the supra-nodes, maximising modularity before moving on to the second stage again. The first and second stages are therefore applied successively until the Louvain Method has approximated a maximum modularity.

10 The main disadvantage of modularity is that it detects communities of average, homogeneous sizes (the sum of internal connections in the communities). These communities of an average size only reflect one aspect of the privileged exchanges between nodes in a graph. A real graph is a complex structure composed of several levels of resolution: small communities may be embedded in bigger communities. Therefore, it does not make more sense to detect average sized communities using modularity on one level than it does to detect small communities. In order to understand the different partitioning scales of a graph, the notion of modularity as implemented in the Louvain Method is modified by introducing a parameter ρ, which conveys the order of magnitude of the size of the communities under study: the small values of ρ favour a partitioning into many communities, and the large values tend towards a small number of communities [Delvenne *et al.*, 2013]. We refer to two other articles for the analysis of the sensitivity of results to the value of ρ [Adam *et al.*, 2017 and Thomas *et al.*, 2017] and opt for a unit value, i.e. the standard version of the Louvain Method.

11 The results are illustrated in the form of maps with an arbitrary choice of colours. The thin lines correspond to the municipalities whereas the thick lines represent the provincial boundaries. The very small meshes which do not include enough observations have been left blank. We know that the Louvain Method is sensitive to the order of interpretation of the nodes; in order to avoid this bias, it is applied 1 000 consecutive times while randomly modifying the order of the nodes between each application, which then allows the strength of the results to be measured: the percentage of times which a node belongs to the same community reflects the stability of the result and the independence of the order of places. This percentage is illustrated by choropleth maps (statistical maps representing relative quantities associated with geographical areas by means of a scale of graduated shades) and/or by hatching on chorochromatic maps (coloured maps representing a nominal variable, in this case belonging to a community). On certain maps, we have also indicated the nodes where there is the highest concentration of connections and which constitute centralities (black dots on the map). To do this, we have taken the number of connections for each Belgian node and have applied the Jenks method[2] to the distribution in order to pinpoint the places with the most connections. Each partition is accompanied by simple statistics such as the number of places in each community and the percentage of places whose classification in the 1 000 applications is unstable. Finally, the similarities between maps are quantified by NMI (Normalized Mutual Information) which measures the quantity of information contained in a map which is also contained in another map. This index has the value 0 when two maps are totally different, and 1 when they are identical [see for example Fred and Jain 2003].

3. Results

12 Each data matrix is the object of a sub-section, the first providing more methodological details. The cartographic comments focus on the essentials, allowing the reader the choice to look at sometimes anecdotal details; we simply propose some avenues for interpretation.

3.1. Commutes to and from the workplace

13 Contrary to expectations, the level of spatial aggregation of data affects neither the optimal number nor the global spatial structure of the communities based on daily home-workplace travel (Figures 2 and 3). The communities calculated based on statistical sectors simply have more detailed outlines, and many sectors are not classified in the absence of observations.

14 Regardless of the level of aggregation, two areas emerge, made up of places which are adjacent to one another: on the one hand, the employment area of Brussels which includes the Brussels-Capital Region, the district of Halle-Vilvoorde and Walloon Brabant, and on the other hand, the area of Leuven which covers the district with the same name, with the exception – unsurprisingly – of some bordering municipalities such as Tervuren, Huldenberg and Kortenberg, which are associated with the Brussels area. Let us underline the fact that Leuven forms a community in itself, not because there is no relationship between this area and the one which is centred on Brussels, but because the places which form the Leuven Community exchange more commuters between themselves than with the rest of the Belgian municipalities (this therefore does not prevent exchanges between the red and orange municipalities on the maps in Figures 2 and 3). Figure 4 illustrates graphically the exchanges between the communities. In order to be legible, the exchanges between communities 1 (Leuven) and 2 (Brussels) are illustrated, while the exchanges between the other communities in Belgium are included in a virtual group named *a*. This circular graph clearly highlights the way in which the Louvain Method classifies the municipalities into communities: the communities have a high level of internal exchanges and a low level of external exchanges.

15 Although the municipality of Nivelles is included in the community of Brabant, it demonstrates a certain instability in terms of classification, which results in a tendency towards exchanges shared with the area of Hainaut (Figure 2). In keeping with the history of employment and the railway infrastructure [see Verhetsel *et al.*, 2009], the area of Brussels is more extensive to the west and southwest, going well beyond the provincial and regional boundaries. Finally, let us note that the provincial boundaries correspond quite closely to the boundaries of the communities, confirming Thomas *et al.* (2017): although these boundaries are debated and tend to be removed, they appear clearly in the functioning of the labour market. In the same line, the linguistic boundary is not permeable in the eastern part of the area under study, whereas from Rixensart/Overijse to the extreme west of the area under study, the linguistic boundary does not at all constitute a barrier in terms of commutes to and from the workplace.

Figure 2. Communities based on commutes to and from the workplace in 2011, on the scale of the statistical sectors
Figure 3. Communities based on commutes to and from the workplace in 2011, on the scale of the municipalities

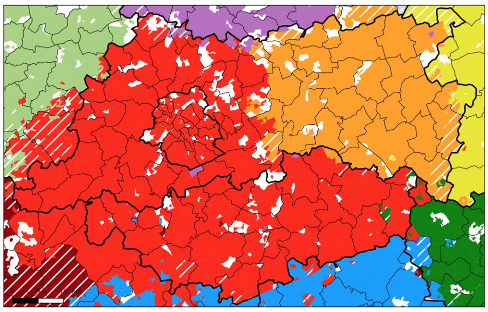


Figure 2

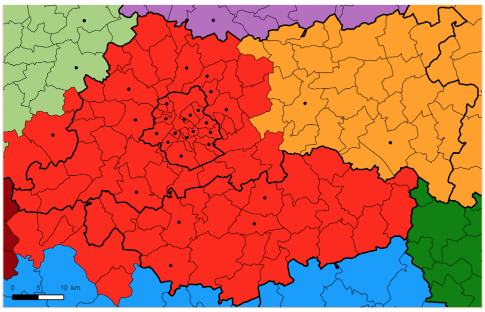
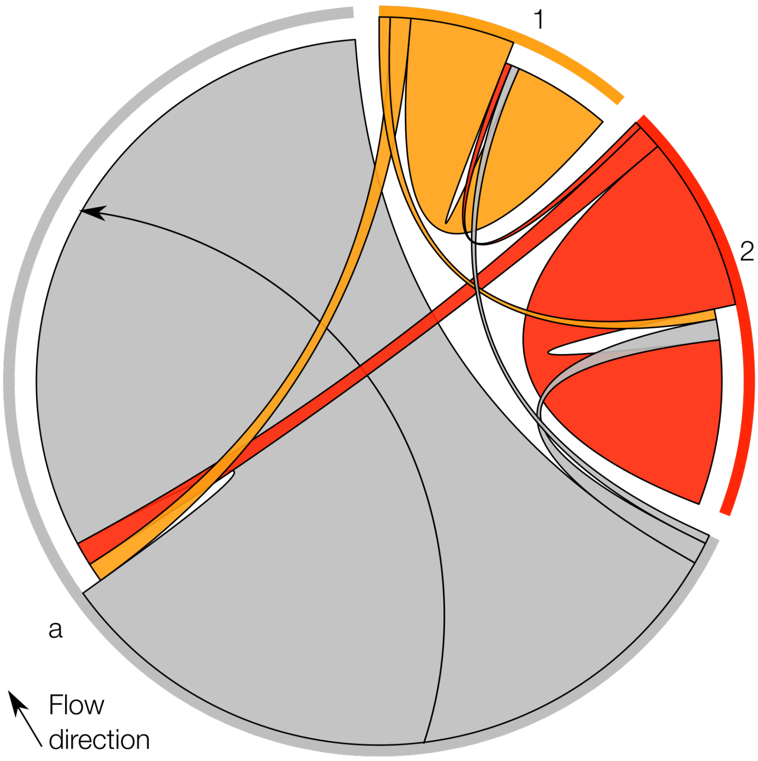


Figure 3

Figure 4. Flow of commutes between communities 1 (Leuven), 2 (Brussels) and all of the other Belgian communities (a)



16 Let us bear in mind that each map is the result of 1 000 applications of the method to a data set and that it is therefore possible to associate a degree of certainty of the classification to each place (see point 2). Figure 3 (as well as Table 1 below) shows that less than 5 % of the nodes are classified in an uncertain manner; they are located mainly at the edge of the province (Londerzeel and Kapellen-op-den-Bos in the north, and Nivelles in the south).

17 With employment basins come employment centres. The Louvain Method does not require a specific central location: it classifies the individuals in a community based on the intensity of the connections between them, independently of the location. In other words, employment centres are not designated *a priori*, and the notion of employment basins could become debatable. However, the calculation of centralities *a posteriori* (see

point 3) highlights most of the municipalities of the Brussels-Capital Region and the adjacent municipalities such as Dilbeek, Asse, Grimbergen, Vilvoorde, Machelen and Zaventem, as well as municipalities such as Halle and Leuven and the employment centres in Walloon Brabant (Wavre, Ottignes-Louvain-la-Neuve, Braine-l'Alleud and Nivelles).

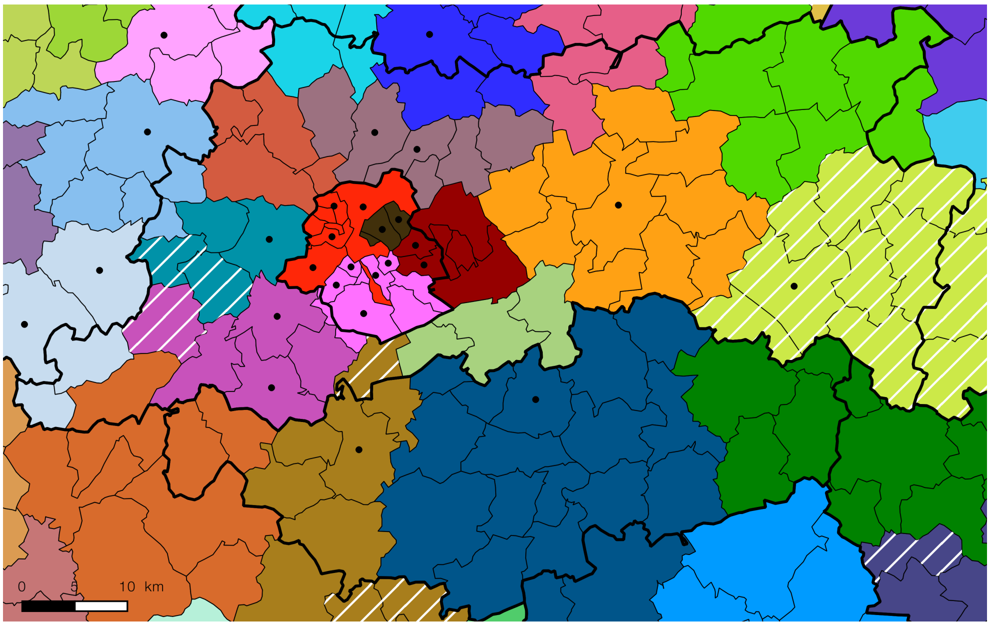
18 In conclusion, this new method of analysis of commuting movements shows that the partitioning into communities leads to strong results (few areas with hatching), that only two basins emerge in an optimal way, that the mesh size (statistical sectors, municipalities) scarcely has little or no impact on the general aspect of the partition, and that the communities are made up of places which are adjacent to one another (distance has an impact on the behaviour of commuters).

3.2. Residential migrations (moves)

19 Residential migrations, commutes to and from the workplace: two types of movement of people between places which respond to totally different mechanisms of spatial choices and territorial practices. It is therefore not surprising that the partitions obtained are different (NMI migrations-commutes: 0,64). The results of the analysis are summarised cartographically in Figure 5: the breaking up of Brabant is much more significant (21 communities instead of 2 for commutes) and results in small groups of municipalities where a change of residence between them is very frequent. Another piece of information – and therefore a partition – is also a constant: the groups are formed of adjacent municipalities. The communities are of a very small size (from 2 to 16 municipalities): the moves in and around Brussels are of a very short distance. While the communities overlap the exterior envelope of the Province of Brabant, only two communities cross the linguistic boundary: thus, Sint-Genesius-Rode/Rhode-Saint-Genèse are part of the same community as Braine-l'Alleud and Nivelles, of course with a slight amount of uncertainty (hatching), and Herne is part of the community centred on Soignies/Braine-le-Comte/Enghien. The Brussels-Capital Region is divided into four communities: (1) a northwest part, (2) a south/southeast part which also includes Linkebeek and Drogenbos, (3) a small community made up of Saint-Josse-ten-Noode, Evere and Schaerbeek, and finally, (4) a community which includes the two Woluwe and continues towards Tervuren and Zaventem [Van Criekingen, 2006; De Maesschalck et al., 2015; Vandermotten et al., 2009].

20 In terms of moves, distance, territory and language have a stronger impact on spatial choices than commutes. The nodes whose classification is uncertain represent 17 % of the total, i.e. a much higher percentage than in the case of commutes (5 %). This therefore means that the partition is less strong than that of commutes (hatching) and that the places are divided between several polarities. The geography of moves can therefore not be used instead of commutes: it involves a completely different spatiality (people may choose a job far from home, from among several employment centres, but when they move they might try to stay near friends, schools, leisure activities, etc.).

Figure 5. Optimal division into communities, based on residential migration data from 2011



3.3. Telephone calls

21 The partitioning into communities of the mobile telephony flow matrix measured from antenna to antenna is represented in Figures 6 and 7. Let us bear in mind that we only had data for the calls for which at least one of the two antennas was located in the Province of Brabant; this is why we have chosen not to map what takes place outside the Province of Brabant. In order to make the chorochromatic maps comparable, Thiessen polygons have been drawn around the antennas and have been classified as communities (Figure 6); these data have also been aggregated on the scale of municipalities and have been partitioned into communities (Figure 7).

22 In keeping with past studies on the scale of Belgium [Blondel *et al.*, 2010; Expert *et al.*, 2011], the mobile telephony areas are composed mainly of places which are adjacent to one another: calls are made more often between people who are near each other. Contrary to point 3.1. above, the spatial aggregation of data affects results slightly in this case. While the general appearance is identical, the optimal number of communities is slightly greater for the fine meshes (eight communities in Figure 6) than for the coarse meshes (five communities in Figure 7). The aggregation erases the spatial details in the case of telephone data: the CBD (Central Business District – heart of Brussels) no longer appears on the aggregated map (Figure 7), the community Braine-l'Alleud/Nivelles is erased and the western part of the outskirts now forms a single community. Aggregation implies a loss of information, which has an impact on spatial partition, while it did not have an impact on commutes, thus confirming other studies under way [see Decuyper *et al.*, 2017].

23 The fine meshes (Figure 5) lead to an urban structure "in sectors" (Hoyt model): the CBD (in red) is very small but includes 4,5 % of the total number of calls: calls are made often despite proximity. The Brussels-Capital Region (outside the CBD) is divided into three communities (west, east and south) which extend spatially well beyond the perimeter of the Region in the same direction, sometimes with a little more uncertainty

as the distance from Brussels increases (hatching). The explanation for this extension is related either to different socioeconomic characteristics or to the fact that, by definition, mobile telephony is possible anywhere and does not involve a workplace or a residence.

24 In terms of telephone relations, the regional boundaries (Brussels) and provincial/ linguistic boundaries are not as well respected as the lines of communities than they are in the case of commutes and migrations. For example, let us point out that the municipalities of Overijse, Huldenberg, Oud-Heverlee and the southern part of the municipalities of Bierbeek, Hoegaarden, Tienen and Landen are part of the telephone area of east Walloon Brabant: the linguistic boundary is therefore much more permeable in terms of telephony, than in terms of residential or pendular migrations. Tubize and Rebecq (French-speaking) are also connected to the telephone community of Halle (Dutch-speaking). Finally, let us note that in this case, the community of Leuven extends towards the municipalities in the north of the province up to Grimbergen.

Figure 6. Mobile telephony areas on the scale of Thiessen polygons around antennas
Figure 7. Mobile telephony areas for aggregated data on the scale of municipalities

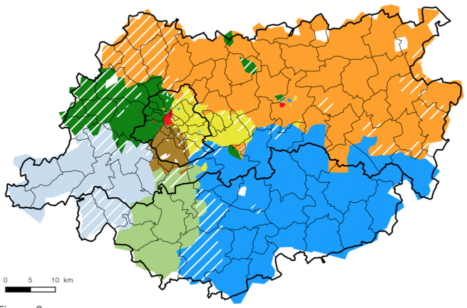


Figure 6

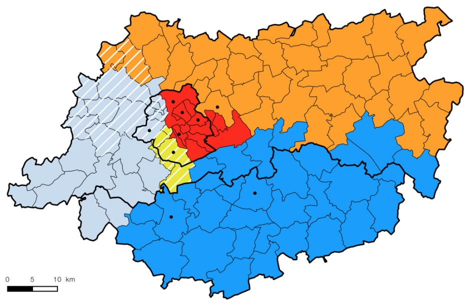
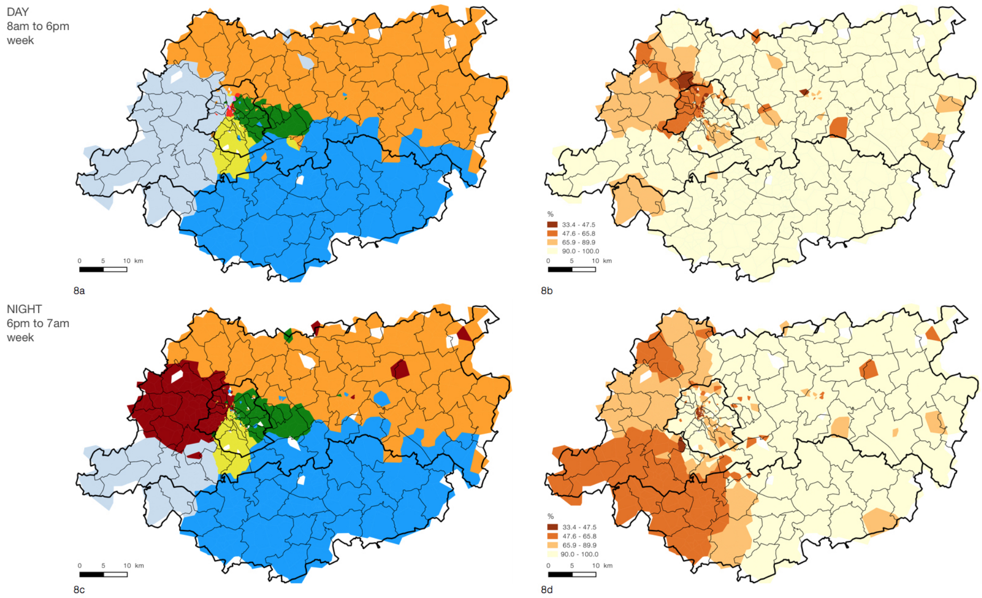


Figure 7

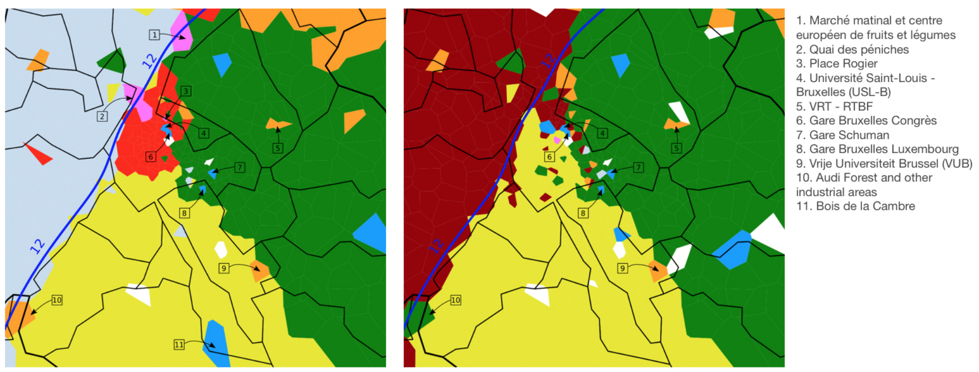
25 In addition to the location, we also have information regarding the time of each call, thus allowing spatial and temporal analyses. For example, Figure 8 illustrates the optimal partitioning into communities during the week for a “daytime” (Figure 8a) and “night-time” period (Figure 8c) on the scale of Thiessen polygons drawn around antennas. The differences between the two maps are smaller than expected (NMI day-night: 0,74) and come down to the disappearance of the CBD at night (empty offices, closed shops) and to a partitioning at night of the western area into two communities: one in the north centred around Asse and Dilbeek (Figure 8c, dark brown) and one in the south centred around Halle and Tubize (Figure 8c, light blue). Figures 8b and 8d supplement this geography by illustrating the strength of the divisions. The choropleth map is preferred here, as the Thiessen polygons are very small, making it difficult to see the hatching on the chorochromatic maps. The largest uncertainties are located in the west of the area under study but also affect some isolated places distributed randomly in the area under study.

Figure 8. Mobile telephony areas on the scale of Thiessen polygons around antennas during the day (8a) and night (8c) as well as the uncertainty of partitions (8b and 8d)



26 Finally, Figure 9 proposes a close-up look at the central part of Figures 8a (day) and another of Figure 8c (night). For the sake of clarity, some place names are mentioned as reference points. Certain polygons form islands, classified as communities which are different from the ones which surround them, thus breaking with the first law of geography (Tobler) at this scale of analysis: each element interacts more with nearby elements than with far-off elements, which we observed clearly on the aggregated scale of municipalities. For example, the antennas covering the areas of VUB and VRT are classified in the community of Leuven, while the antennas covering the Luxembourg, Schuman and Congrès stations are classified in the community of Walloon Brabant. These structures are detected for calls made during the day (Figure 9a) as well as the night (Figure 9b).

Figure 9. Mobile telephony areas (close-up of the centre of Brussels)



9a. Calls during the day (close-up of Figure 8a)

9b. Calls during the night (close-up of Figure 8c)

27 We may conclude here that in terms of telephone communities, the city goes beyond the boundaries of the Brussels-Capital Region and that the linguistic boundary is not scrupulously adhered to by the boundaries of the communities, contrary to what was mentioned by Blondel *et al.* [2010] on the scale of the country. This is due to the nature of the data: Blondel *et al.* [2010] used billing addresses, whereas we have used the

location at the moment of the call; let us also add that the data were from another telephone provider and that the two analyses were carried out seven years apart.

28 In conclusion, Table 1 summarises the results obtained for each database in terms of optimal number of communities (*n*) and as a percentage (%) of places (nodes) whose inclusion in a group is uncertain. These quantities corroborate the map commentaries: very small communities whose numbers are therefore high for moves, and a high level of uncertainty in terms of classification for telephone calls.

Table 1. Comparison of partitions obtained in the Province of Brabant

	n	%
Figure 2 Commutes (stat. sectors)	2	3,9
Figure 3 Commutes (municipalities)	2	4,5
Figure 5 Moves (municipalities)	21	16,6
Figure 6 Telephones (antennas)	8	21,3
Figure 7 Telephones (municipalities)	5	19,8
Figure 8a Telephones (antennas - day)	7	35,4
Figure 8c Telephones (antennas - night)	7	40,0

(*n*: optimal number of communities detected; %: percentage of places whose inclusion in a community is not stable over 1 000 applications)

Conclusion

29 The detection of communities in (large) relational databases is a recent approach whose applications in a metropolitan area are still rare and in their infancy [Zhong *et al.*, 2014]. The case of Brussels allows us to illustrate the structuring power of inter-relations between places, using three examples of data. The cartographies proposed show communities of places with strong relationships (w_{ij}) and allow the space in Brussels to be defined and partitioned. They illustrate the complex urban spatial reality (in Brussels), and call to mind the importance of having a proper understanding of the nature of the variable used before drawing operational conclusions. Let us review one by one the questions raised in the introduction:

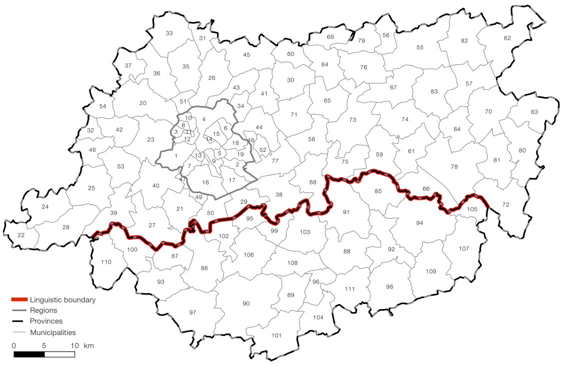
1. Commutes, changes of residence and telephone flows are the three databases used here. Due to their definition, they lead to different spatial structures (number, composition of communities). The shape and the number of areas depend greatly on the data used. This fact is not surprising in itself, and it is worthwhile to bear it in mind at a time when there are more and more data-crunching urban models due to the huge amount of data available. During the analysis of the map, it is important to question the nature and limitations of data and methods. However, the maps refer to relatively strong and often known spatial structures, as though the space and in particular the urban network had reached a certain

"equilibrium" [suggested by Fujita and Thisse, 2013 and discussed at length by Pumain, 2017].

2. The communities which are extracted mathematically are generally made up of places which are adjacent to one another, while geolocation (and therefore the distance between places) is not part of the method used (Louvain Method). This reinforces the idea that relationships are stronger between nearby places, in keeping with Gaspar and Glaeser [1998], Fujita and Thisse [2013, p. 191] and in reference to Tobler's law (1970), which is well known among geographers ("Everything is related to everything else, but near things are more related than distant things" [Sui, 2004]), and even to gravity models such as that of Reilly [1932].
3. The communities go beyond the boundaries of the Brussels-Capital Region, confirming the sprawling of the metropolitan territory [Thomas *et al.*, 2012]. Strong spatial structures emerge from the three databases: the communities anchored in the Brussels-Capital Region extend towards the outskirts (outside BCR), Leuven proves to be an area of interactions in itself, and to the west of the area under study, a spatial reality centred on Asse and Halle emerges. Walloon Brabant presents a geography which depends greatly on the nature of interactions: it forms a whole in terms of commutes to and from the workplace and four distinct areas in terms of mobile telephony (Tubize, Braine-l'Alleud/Nivelles, the "tripole" Wavre/Ottignies/Louvain-la-Neuve and Jodoigne in the east). There are therefore very stable groups of places, and others which are more uncertain, reinforcing certain results published for other cities [Lawlor et al., 2012] and the multiplicity of facets of a city.
4. The communities in Brussels extend beyond the regional boundaries, shaking up somewhat the political division into three Regions. This therefore calls for great caution and for these realities to be well understood using tools and *ad hoc* theories, as a consistent policy cannot be pursued if the boundaries observed do not correspond with those in the planning [reinforcing De Maesschalk *et al.,* 2015 and Liu *et al.*, 2015 for other places and other problems]. We may therefore also question the conclusions of studies limited to Flanders and Wallonia (with or without Brussels). However, and more surprisingly, the provincial boundaries often constitute those of communities when they are destined to disappear [Thomas *et al.*, 2017].
5. The methods used apply in particular to large databases. We know that today, public and private services have new untapped sources of data which are georeferenced; we may therefore encourage them to equip themselves with observatories and specific tools or to make these data accessible, as they allow an analysis of realities which are otherwise difficult to measure (for example the population during the day and night via telephone calls). They constitute a true potential to understand urban processes and to improve planning and governance.

30 Data science and large databases (big data) constitute new and useful tools for urban analysts, but it is necessary to go beyond cartographic and technological wonder, and to truly understand the new elements they bring in terms of comprehending, measuring and modelling urban complexity. This is the discussion which we have tried to initiate here.

Annexe. Municipalities of the former Province of Brabant



1. Anderlecht	17. Watermael-Boitsfort	33. Londerzeel	49. Linkebeek	65. Herent	81. Linter	97. Nivelles
2. Auderghem	18. Woluwe-Saint-Lambert	34. Machelen	50. Sint-Genesius-Rode	66. Hoegaarden	82. Scherpenheuvel-Zichem	98. Perwez
3. Berchem-Sainte-Agathe	19. Woluwe-Saint-Pierre	35. Meise	51. Wemmel	67. Holsbeek	83. Tielt-Winge	99. Rixensart
4. Bruxelles	20. Asse	36. Merchtem	52. Wezembeek-Oppem	68. Huldenberg	84. Glabbeek	100. Tubize
5. Etterbeek	21. Beersel	37. Opwijk	53. Lennik	69. Keerbergen	85. Beauvechain	101. Villers-la-Ville
6. Evere	22. Bever	38. Overijse	54. Affligem	70. Kortenaken	86. Braine-l'Alleud	102. Waterloo
7. Forest	23. Dilbeek	39. Pepingen	55. Aarschot	71. Kortenberg	87. Braine-le-Château	103. Wavre
8. Ganshoren	24. Galmaarden	40. Sint-Pieters-Leeuw	56. Begijnendijk	72. Landen	88. Chaumont-Gistoux	104. Chastre
9. Ixelles	25. Gooik	41. Steenokkerzeel	57. Bekkevoort	73. Leuven	89. Court-Saint-Etienne	105. Hélécine
10. Jette	26. Grimbergen	42. Ternat	58. Bertem	74. Lubbeek	90. Genappe	106. Lasne
11. Koekelberg	27. Halle	43. Vilvoorde	59. Bierbeek	75. Oud-Heverlee	91. Grez-Doiceau	107. Orp-Jauche
12. Molenbeek-Saint-Jean	28. Herne	44. Zaventem	60. Boortmeerbeek	76. Rotselaar	92. Incourt	108. Ottignies-Louvain-la-Neuve
13. Saint-Gilles	29. Hoeilaart	45. Zemst	61. Boutersem	77. Tervuren	93. Ittre	109. Ramillies
14. Saint-Josse-ten-Noode	30. Kampenhout	46. Roosdaal	62. Diest	78. Tienen	94. Jodoigne	110. Rebecq
15. Schaerbeek	31. Kapelle-op-den-Bos	47. Drogenbos	63. Geetbets	79. Tremelo	95. La Hulpe	111. Walhain
16. Uccle	32. Liedekerke	48. Kraainem	64. Haacht	80. Zoutleeuw	96. Mont-Saint-Guibert	

BIBLIOGRAPHY

ADAM, A., DECUYPER, A., DELVENNE, J-C., THOMAS, I., 2017. *On the robustness of the Louvain Method to detect communities: examples on Brussels* (submitted)

ANAS , A., ARNOTT, R., SMALL, K., 1998. Urban spatial structure. In: *Journal of Economic Literature*. vol. 36, no 3, pp. 1426-1464

BLONDEL, V., GUILLAUME, J., LAMBIOTTE, R., LEFEBVRE, E., 2008. Fast unfolding of communities in large networks. In: *Journal of statistical mechanics: theory and experiment*. 10/2008, vol. 2008, no 10, P10008.

BLONDEL, V., KRINGS, G., THOMAS, I., 2010. Regions and borders of mobile telephony in Belgium and in the Brussels metropolitan zone, In: *Brussels Studies*. 10/2010, n° 42, 12 p. Available on: https://brussels.revues.org/806

BOUSSAUW, K., ALLAERT, G., WITLOX, F., 2012. Colouring inside what lines? Interference of the urban growth boundary and the political-administrative border of Brussels. In: *European Planning Studies*. vol. 21, no 10, pp. 1509-1527

DEBUSSCHERE, M., LUSYNE, P., DEWITTE P., BAEYENS, Y., DE MEERSMAN, F., SEYNAEVE, G., WIRTHMANN, A., DEMUNTER, C., REIS, F., REUTER, H., 2017. *Big data et statistiques : un recensement* *tous les quarts d'heure.* Available on: http://statbel.fgov.be/fr/binaries/analyse_bigdata_fr_tcm326-281473.pdf

DECUYPER, A., CLOQUET, C., THOMAS, I., DELVENNE, J.-C. , 2017. *On the issue of aggregation for community detection in social networks* (to be submitted)

DELVENNE, J.-C., SCHAUB, M.T., YALIRAKI, S.N., BARAHONA, M., 2013. The stability of a graph partition: A dynamics-based framework for community detection. In: *Dynamics On and Of Complex Networks*, Vol. 2, pp. 221–242. Springer.

DE MAESSCHALK, F., DE RIJCK, T., HEYLEN, V., 2015. Crossing Borders: Social-spatial Relations between Brussels and Flemish Brabant. In: *Brussels Studies*, no 84. Available on: https://brussels.revues.org/1260

DOBRUSZKES, F., VANDERMOTTEN, C., 2006. Eléments pour une géographie des clivages philosophiques à Bruxelles. In: *L'Espace Géographique*, tome 35, pp. 31-43.

DUJARDIN, C., THOMAS, I., TULKENS, H., 2007. Quelles frontières pour Bruxelles ? Une mise à jour. In: *Reflets et Perspectives de la Vie Economique*, Tome XLVI –2007/2-3, pp. 155-176.

DURANTON, G., 2015. Delineating Metropolitan Areas: Measuring Spatial Labor Market Networks Through Commuting Patterns, In: T. WATANABE et al. (Eds.). *The Economics of Interfirm Networks, Advances in Japanese Business and Economics 4*, pp. 107-132.

EGGERICKX, T., HERMIA J.-P., SURKIJN, J., WILLAERT, D., 2012. Les migrations internes en Belgique. In: *Monographies Enquête Socio-économique 2001*, n° 2, Brussel, SPF Economie en Politique Scientifique Fédérale. 200 p.

EXPERT, P., EVANS, T., BLONDEL, V., LAMBIOTTE, R., 2011. Uncovering space-independent communities in spatial networks. In: *Proceedings of the National Academy of Sciences*, 108(19), 7663-7668.

FORTUNATO, S., 2010. Community detection in graphs. In: *Physics Reports*. 02/2010. vol. 486, no 3-5, pp. 75-174.

FRED, A., JAIN, A., 2003. Robust data clustering. In: *Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition*. vol. 2, pp. II-128.

FUJITA, M., THISSE, J.-F., 2013. *Economics of agglomeration. Cities, Industrial Location, and Globalization*. Cambridge University Press, 528 p.

GASPAR, J., GLAESER, E., 1998. Information technology and the future of cities. In: *Journal of Urban Economics*, vol. 43, n° 1, pp. 136-156.

IOANNIDES, Y., 2012. *From Neighborhoods to Nations: The Economics of Social Interactions*. Princeton University Press.

HAO, J., ZHY, J., ZHONG, R., 2015. The rise of big data on urban studies and planning practices in China: Review and open research issues. In: *Journal of Urban Management*, 12/2015, vol. 4, no 2, pp. 92-124.

LAWLOR, A., COFFEY, C., MCGRATH, R., POZDNOUKHOV, A., 2012. *Stratification structure of urban habitats, Maynooth University reprint.* Available on: eprintsprod.nuim.ie/3940/1/AP_stratified_habitats.pdf

LIU, X., GONG, L., GONG, Y., LIU, Y., 2015. Revealing travel patterns and city structure with taxi trip data, In: *Journal of Transport Geography*. 02/2015, vol. 43, pp. 78–90

NEWMAN, M., GIRVAN, M., 2004. Detecting community structure in networks. In: *The European Physical Journal B*. 03/2004, vol. 38, nr. 2, pp. 321–330.

PUMAIN, D., 2017. Geography far from equilibrium. In: JOHNSON, J. *et al.* (Eds), *Non-equilibrium social science and Policy*, Springer International, pp. 71-80

RATTI, C., SOBOLEVSKY, S., CALABRESE, F., ANDRIS, C., READES, J., MARTINO, M., CLAXTON, R., STROGATZ, S., 2010. Redrawing the map of Great-Britain from a network of human interactions. In: *PlosOne*. 08/12/2010, vol. 5, no 12, e14248 .

SAGL, G., DELMELLE, E., DELMELLE, E., 2014. Mapping collective human activity in an urban environment based on mobile phone data. In: *Cartography and Geographic Information Science*. vol. 41, no 3, pp. 272-285.

SUI, D., 2004. Tobler's First Law of Geography: A Big Idea for a Small World? In: *Annals of the Association of American Geographers,* vol. 94, no 2, pp. 269-277.

THOMAS, I., ADAM, A., VERHETSEL, A., 2017. Migration and commuting fields within Belgium: A new geography with a community detection algorithm. In: *e-Belgeo* (en révision)

THOMAS, I., COTTEELS, C., JONES, J., PEETERS, D., 2012. Revisiting the extension of the Brussels urban agglomeration: new methods, new data... new results? In: *e-Belgeo* (en ligne). Available on: http://belgeo.revues.org/6074

THOMAS, I., VERHETSEL, A., LORANT, V., 2009. Le recensement de la population : un requiem ? In: *Regards Economiques,* no 67, 8 p.

TOBLER, W. 1970. A computer movie simulating urban growth in the Detroit region. In: *Economic Geography*, vol. 46, pp. 234-240.

VAN CRIEKINGEN, M., 2006. Que deviennent les quartiers centraux à Bruxelles ? In: Brussels Studies, no 1. Available on: http://brussels.revues.org/293

VANDERMOTTEN, C., 2016. Adéquations et inadéquations du découpage territorial aux contextes politiques et économiques. Le cas de la Belgique. In: *EchoGéo*, no 35

VANDERMOTTEN, C., LECLERCQ, E., CASSIERS, T., WAYENS, B., 2009. L'économie bruxelloise. In: *Brussels Studies*, Notes de synthèse. Available on: http://brussels.revues.org/934

VAN HAMME, G., GRIPPA, T., VAN CRIEKINGEN, M., 2016. Migratory movements and dynamics of neighbourhoods in Brussels. In: *Brussels Studies,* no 97. Available on: http://brussels.revues.org/1338

VAN HECKE, E., HALLEUX, J.-M., DECROLY, J.-M., MERENNE-SCHOUMAKER, B., 2007. Noyaux d'habitat et régions urbaines dans une Belgique urbanisée. In: *Monographies Enquête Socio-économique*, 2001, no 9, Bruxelles, SPF Economie en Politique Scientifique Fédérale. 201 p.

VERHETSEL, A., VAN HECKE, E., THOMAS, I., BEELEN, M., HALLEUX, J., LAMBOTTE, J., RIXHON, G., MERENNE-SHOUMACKER, B., 2009. Le mouvement pendulaire en Belgique. Les déplacements domicile-lieu de travail. Les déplacements domicile-école. In: *Monographies Enquête Socio-économique 2001*, no 10, Brussel, SPF Economie en Politique Scientifique Fédérale, 217 p.

ZANDBERGEN, P., 2009. Accuracy of iPhone Locations: A comparison of assisted GPS, WiFi and cellular positioning. In: *Transactions in GIS*, no 3, pp. 5-25.

ZHONG, C., ARISONA, S., HUANG, X., BATTY, M., SCHMITT, G., 2014. Detecting the dynamics of urban structure through spatial network analysis. In: *International Journal of Geographical Information Science*, 2178-2199.

NOTES

1. The Thiessen polygon centred on a given antenna is made up of places which are closer to this antenna than to other antennas.

2. The Jenks method is a discretisation method which minimises intra-class variance and maximises inter-class variance.

ABSTRACTS

Using conventional relational data (residential migrations, commutes to and from the workplace) and less conventional relational data (mobile telephony calls), the space in and around the Brussels-Capital Region is partitioned into groups of closely inter-related places using a mathematical community detection method. The partitions obtained lead to strong spatial structures, while neither the distance nor the characteristics of the places are taken into account in this method. This article illustrates how large databases (big data) and their specific methods provide new opportunities for urban analyses (delimitation of urban borders, formalisation of intra-urban structures), and remind us here that no structure may be interpreted without a thorough understanding of data, the tools used and regional and urban theories.

A l'aide de données relationnelles conventionnelles (migrations résidentielles, navettes de travail) et moins conventionnelles (appels de téléphonie mobile), l'espace dans et autour de la Région de Bruxelles-Capitale est partitionné en groupes de lieux fortement inter-reliés à l'aide d'une méthode mathématique de détection de communautés. Les partitions obtenues conduisent à des structures spatiales fortes alors que ni la distance ni les caractéristiques des lieux ne sont prises en compte par la méthode. Cet article illustre comme les grandes bases de données (*big data*) et leurs méthodes spécialement dédiées offrent de nouvelles opportunités pour les analyses urbaines (délimitation des bordures urbaines, formalisation des structures intra-urbaines) et donnent ici l'occasion de rappeler qu'aucune structure ne peut s'interpréter sans la maîtrise des données, des outils utilisés mais aussi des théories régionales et urbaines.

Aan de hand van conventionele (woonmigraties en woon-werkverplaatsingen) en minder conventionele (mobiele telefoongesprekken) relationele gegevens wordt de ruimte in en rond het Brussels Hoofdstedelijk Gewest opgedeeld in groepen van plaatsen, die nauw met elkaar verbonden zijn, op basis van een wiskundige methode voor de detectie van gemeenschappen. De verkregen indelingen (partities) leiden tot sterke ruimtelijke structuren, hoewel de methode geen rekening houdt met de afstand en de karakteristieken van de plaatsen. Dit artikel licht toe dat de grote databanken (*big data*) en hun speciaal daarvoor bestemde methodes nieuwe mogelijkheden voor stadsanalyses (afbakening van de stadsranden en formalisering van de intrastedelijke structuren) aanreiken en een kans bieden om eraan te herinneren dat geen enkele structuur geïnterpreteerd kan worden zonder de gegevens, gebruikte instrumenten maar ook de regionale en stedelijke theorieën te kennen.

INDEX

Mots-clés: aire métropolitaine, développement territorial
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